AD

12

TECHNICAL REPORT
TR-77-005-FEL

EFFECT OF COMBINED IRRADIATION AND THERMAL PROCESSING ON CANNED BEEF

Irradiated Food Products Group
Radiation Preservation of Food Division

Approved for public release;
distribution unlimited.

June 1976

Food Engineering Laboratory
FEL-50

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER NATICK TR-7T/005	2. GOVT ACCESSION NO. (9) / 3. RECIPIENT'S CATALOG NUMBER Technical rept.
4. TITLE (and Subtitle) (6) EFFECT OF COMBINED IRRADIATION AND THERMAL PROCESSING ON CANNED BEEF.	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER (14) FEL-60
7. AUTHOR(s) (10) John J. Howker, Gary W. Shults and Eugen Wierbicki	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Natick Research & Development Command ATTN: DRXNM-WRI Kansas St., Natick, MA 01760	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (16) 1T762724AH99 631 25 414 001
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Natick Research and Development Command ATTN: DRXNM-WRI Natick, MA 01760	12. REPORT DATE (11) June 1976 (12) 34p.
	13. NUMBER OF PAGES 32
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

(18) NARADCOM

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

(19) TR-77-005-FEL

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

IRRADIATION	CANNED BEEF	STERILIZATION
THERMAL PROCESSING	BEEF	FOOD PRESERVATION
HEAT	CANNING	ADDITIVES
PROCESSING	LOW DOSE IRRADIATION	SALTING

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objectives of these experiments were to determine if a superior beef product could be developed utilizing a combination of low dose irradiation and thermal processing.

Meat rolls were prepared using fresh beef semi-membranosus muscle, sodium chloride (0.75%), sodium tripolyphosphate (0.4%) and formed by mild heat treatments. The rolls were packed in cans and then subjected to several combinations of irradiation and thermal treatments. The experimental meats were

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

408903

evaluated for sensory characteristics, preference and for moisture retention (cooking losses).

Under the conditions studied, a combined treatment consisting of cookhouse processing (90% yield), 25 kJ/kg irradiation and thermally processed to an internal temperature of 90°C yielded the most acceptable product. This product scored slightly better than enzyme-inactivated radappertized beef (47 kJ/kg) for color, odor, flavor, and preference.

The value of the combined treatment, as tested, is questionable due to excessive cooked-out juice, and only slight improvement in quality; additional work is required to produce the product.

PREFACE

These experiments are a part of a continuing investigation to improve the sensory characteristics of irradiated meat products. The objectives of these experiments were to determine if a superior beef product could be developed utilizing a combination of low dose irradiation and thermal processing.

Results from these investigations have shown that a combined treated beef product scored slightly better for color, odor, flavor, and preference than radappertized beef. The value of combined treatment, as tested, is questionable due to excessive cooked-out juice and only slight improvement in product quality.

These studies were undertaken as a research project by the Irradiated Food Products Groups, Radiation Preservation of Food Division, Food Engineering Laboratory, under Project 1T762724AH99D.

TABLE OF CONTENTS

LIST OF TABLES

Table 16. Sensory and preference scores of beef as affected by thermal sterilization, irradiation, or sequence of irradiation and thermal processing.

Table 17. pH and total organic volatiles of beef as affected by thermal sterilization, irradiation, or sequence of irradiation and thermal processing.

EFFECT OF COMBINED IRRADIATION AND THERMAL PROCESSING ON CANNED BEEF

INTRODUCTION

The degree of irradiation necessary to produce a nonrefrigerated shelf-stable, sterile, canned meat generally affects the meat's flavor, texture, and appearance (Hannan 1975,[1] Shultz et al., 1956).[2] The temperature required to thermally sterilize canned meat also impairs the sensory characteristics (Stumbo, 1949).[3] In both processes the degree of the degradation increases with severity of treatment. Consequently, new sterilizing techniques that retain or improve the sensory properties without lowering product safety are constantly being sought. Combined irradiation-heat processing is synergistic for destruction of bacterial spores (Morgan and Reed 1954;[4] Kempe 1955;[5] Kan et al., 1957;[6] Sommer et al., 1967).[7] As reduced quantities of irradiation and heat can be used because of their

[1] Hannan, R. S. 1955. Scientific and Technological Problems Involved in Using Ionizing Radiations for the Preservation of Food. Special Report No. 61, Department of Scientific and Industrial Research, Her Majesty's Stationery Office, London.

[2] Shultz, H. W., Can, R. F., Nordan, H.C., and Morgan, B.H., 1956. Concomitant Use of Radiation With Other Processing Methods of Meat. Food Technol. 10: 233.

[3] Stumbo, C. R., 1949. Thermobacteriology as Applied to Food Processing. Advances in Food Research, 2. Academic Press, Inc., New York City, New York.

[4] Morgan, B. H. and Reed, J. M., 1954. Resistance of Bacterial Spores to Gamma Radiation. Food Res. 19: 357.

[5] Kempe, L. L., 1955. Combined Effects of Heat and Radiation in Food Sterilization. Appl. Microbiol. 3: 346.

[6] Kan, B., Goldblith, S. A., and Proctor, B. E., 1957. Complementary Effects of Heat and Ionizing Radiation. Food Res. 22: 509.

[7] Sommer, N. F., Fortlage, R. J., Buckley, P. M., and Maxie, E. C., 1967. Radiation Heat Synergism for Inactivation of Market Disease Fungi of Stone Fruits. Phyto-Pathology 57: 428.

synergistic effect on the destruction of bacterial spores, a combined processing could be useful for food preservation (Purohit et al., 1971).[8] Recent advances in radappertized meats included the use of additives (salt, TPP), partial dehydration and irradiation at cryogenic temperatures (Wadsworth et al., 1966;[9] Heiligman et al., 1972;[10] Shults et al., 1972,[11] 1973,[12] 1974).[13] This study is concerned with the effect of combined treatment and other processing techniques on the sensory characteristics of canned beef.

Materials and Methods

Meat Rolls-to be Radappertized

Top round USDA inspected beef, grade Commercial or better, was trimmed of excess fat and cut into pieces (57 g to 681 g). The beef pieces were mixed with 0.75% salt (NaCl), 0.4% sodium tripolyphosphate (TPP) and 3% crushed ice in a mechanical mixer (Hobart Model No. H-600-D) for 15

[8] Purohit, K. S., Manson, J. E., and Zahrandnik, J. W., 1971. Theoretical Evaluation of Combined Irradiation and Thermal Processes in Cylindrical Containers with Gamma Sources. J. Food Sci. 36:750.

[9] Wadsworth, C. K. and Shults, G. W., 1966. Low Temperature Irradiation of Meat. Activities Report 18:13.

[10] Heiligman, F. and Rice, L. J., 1972. Development of Irradiation Sterilized Codfish Cake. J. Food Sci. 37:469.

[11] Shults, G. W., Russell, P. R., and Wierbicki, E., 1972. Effect of Condensed Phosphates on pH, Swelling, and Water-Holding Capacity of Beef. J. Food Sci. 37:860.

[12] Shults, G. W. and Wierbicki, E., 1973. Effect of Sodium Chloride and Condensed Phosphates on Water-Holding Capacity, pH, and Swelling of Chicken Muscle. J. Food Sci. 38:991.

[13] Shults, G. W. and Wierbicki, E., 1974. Effects of Condensed Phosphates on the pH, Water-Holding Capacity and Meat Swelling Properties of Pork Muscle. TR-74-22-FL. US Army Natick Laboratories.

minutes. The mixture was stuffed under pressure into drilled fibrous, easy peel casings* and were refrigerated for at least 2 hours but not more than 24 hours prior to processing. The rolls were enzyme-inactivated in a cookhouse operating as follows: three hours at 65°C; then hourly increases of 6°C to reach a temperature of 90°C. The enzyme-inactivated process was controlled to produce an internal temperature of 65°C to 75°C. After radappertization, the enzyme-inactivated beef was used for comparison with the combined beef.

Meat Rolls - to be Processed by Combined Radiation and Heat

Meat rolls for combined treatment were processed similar to the radappertized beef up to the enzyme-inactivation stage. The rolls were prepared by three methods: (1) three hours in the cookhouse (65°C) to form and shape the rolls; then temperature of the cookhouse was increased to 71°, 77°, and 83°C to dehydrate the meat to desired yields of 100%, 90%, and 80%, respectively; (2) immersion in a 70°C water bath for 1 hour; (3) heating in a conduction oven operating at 135°C for 2 hours.

Canning

The meat rolls were chilled to 3°C, casings removed and cut into 624 ± 5 g sections, packed in 404 x 309 epoxy phenolic lined cans and sealed at 8.4 kPa pressure. After canning, the meat was stored at -29°C.

Irradiation

Prior to irradiation, the product temperature was lowered to -30°C ± 5°C and maintained at this temperature during irradiation by controlled liquid nitrogen flow. The cans were gamma-irradiated using the US Army Natick Research and Development Command's $Cobalt_{60}$ facility. The beef for combined treatment products received doses of 15, 25, 30 kJ/kg ± 5%. The enzyme-inactivated beef was radappertized at 47 kJ/kg ± 5%. The dose rate and time varied due to Co_{60} source depletion and subsequent replenishment.

Thermal Processing

Thermal processing was scheduled for both pre- and postirradiation processing. The cans were thermally processed at retort temperatures of 105°, 110°, and 120°C to internal meat temperatures of 70°, 90°, 100°, and 110°C. Internal temperatures were monitored with meat-filled thermocouple cans.

*No. 6½ Visking

The cans were chilled in ice water immediately after heat-processing to prevent further cooking.

Evaluations:

Physical Evaluation Formed rolls were weighed before and after cooking to determine cooking loss. The combined treated cans were evaluated both for meat weight and cooked-out juices.

Chemical Analysis Moisture, protein, fat, salt, and ash were determined by the standard AOAC methods (1970).[14] Free fatty acid (FFA) were determined by methods described by Pearson (1971);[15] thiobarbituric acid (TBA) values, Tarladgis et al.,(1960)[16] and total organic reducing volatile quantities, Shults et al., (1976).[17]

Sensory Evaluation

The samples were initially screened by a 12-member technological group for color, odor, texture, and appearance on a 9-point scale (1 signifying "extremely poor" and 9 "excellent"). The samples were also evaluated by a trained technical panel (8-12 members) and rated for preference using

[14] AOAC, 1970. "Official Methods of Analysis," 11th Ed. Assn. of Official Agric. Chemists, Washington, D. C.

[15] Pearson, D., 1971. "Chemical Analyzing of Food," 6th Ed., p.377. Chemical Publishing Company, New York, New York.

[16] Tarladgis, B. C., Watts, B. M., and Younathan, M. T., 1960. A Distillation Method for the Quantitative Determination of Malonaldehyde in Rancid Foods, J. Am. Oil Chem. Soc. 37: 44.

[17] Shults, G. W., Howker, J. J., and Wierbicki, E., 1976. Effect of Salt and Foodgrade Phosphate on Texture, Organic Volatiles and Sensory Characteristics of Irradiated and Nonirradiated Pork. J. Food Sci. 41: 1096.

the 9-point hedonic scale (Peryam and Pilgrim 1957)[18] and for discoloration, off odor, irradiation flavor, off flavor, mushiness and friability using the 9-point intensity scale (1 signifying "none" and 9 indicating "extreme").

Statistical Analysis

The sensory evaluation results were analyzed by methods described by Steel and Torrie (1960).[19]

Experimental, Results and Discussion

Effect of beef roll yield and meat internal temperature on combined treated beef. Beef rolls were processed in the cookhouse to yields of 100%, 90%, and 80% by weight. The formed meat was cut into pieces, packed in cans, and vacuum-sealed. The cans were irradiated at 25 kJ/kg $\pm$ 5% at $-30^{\circ}C \pm 10^{\circ}C$, and then retorted to meat internal temperatures of 70°, 90°, and $100^{\circ}C$ using a retort temperature of $105^{\circ}C$. An additional set was retorted to $110^{\circ}C$ using a retort temperature of $121^{\circ}C$. The cans were immediately chilled to ambient temperature to prevent further cooking.

Table 1 presents the proximate analysis of combined treated beef (90% yield). Table 2 shows the results of cooked-out juice. As expected, the rolls processed to 80% yield out of the cookhouse had less juice than the rolls cooked to only 90% and 100% yield. It is interesting to note that the internal temperature obtained during retorting had little, if any effect on the quantity of cooked out juice.

[18] Peryam, D. R. and Pilgrim, F. J., 1957. Hedonic Scale Method for Measuring Food Preferences. Food Technol. (Supp) 11:9.

[19] Steel, R. G., and Torrie, J. H., 1960. Principles and Procedures of Statistics, McGraw-Hill Book Company, 1st Ed.

Irradiation at 25 kJ/kg and retorting to 100° or $110^{\circ}C$ resulted in an overcooked beef characterized by poor texture and strong "canned meat" odor (Table 3). The meat processed to $70^{\circ}C$ and $90^{\circ}C$ scored high in preference (Table 4) and superior to the 47 kJ/kg irradiated enzyme-inactivated reference samples.

Effect of retort temperature and meat internal temperature on combined-treated beef.

Formed beef rolls, cookhouse processed to a 90% yield were cut into pieces, vacuum-canned and irradiated at 25 kJ/kg $\pm$ 5% at $-30^{\circ}C \pm 10^{\circ}C$. The irradiated cans were retorted at $110^{\circ}C$ and $120^{\circ}C$ to internal temperatures of 70°, 90°, and $100^{\circ}C$.

The percent "cooked-out" juice (Table 5) differed slightly per retort and internal temperature. Table 6 data indicates the beef retorted at $110^{\circ}C$ was preferred to that retorted at $120^{\circ}C$, and internal temperature had no effect on preference scores. The combined-treated beef scored higher than the 47 kJ/kg. irradiated enzyme-inactivated reference sample.

The effect of meat roll processing methods on combined-treated beef.

Beef rolls were formed by the following methods: (1) cookhouse processing to a 90% yield; (2) immersion for 1 hour in a $70^{\circ}C$ water bath; and (3) by heating in a conduction oven at $135^{\circ}C$ for 2 hours. These rolls were compared with nonformed raw meat and enzyme-inactivated rolls (65°-$75^{\circ}C$ internal temperature) for weight loss. The water bath and oven formed rolls had less loss in weight (Table 7).

The formed meat rolls were cut into pieces, vacuum-sealed in cans, irradiated at 25kJ/kg $\pm$ 5% at $-30^{\circ}C \pm 5^{\circ}C$, and retorted (at $110^{\circ}C$) to meat internal temperatures of 70°, 90°, and $100^{\circ}C$.

The cans containing enzyme-inactivated irradiated reference beef had no cooked-out juice (Table 8). The amount of cooked-out juice in the

nonformed raw irradiated beef cans was less than the amount of juice resulting from the other roll-forming procedures, but the meat was unacceptable due to lack of meat coherence, poor texture, poor color, and adhesion to the can surface. The cans of water bath and oven formed irradiated beef contained about the same quantities of juice: 18%-19%. The cans of 90% yield irradiated beef contained approximately 16% juice. The internal temperatures (70^{o}, 90^{o}, $100^{o}C$) had little effect on the quantity of cooked-out juice.

The oven formed beef samples were eliminated as the result of this process and the water-bath, formed were similar (Tables 8,9). The $70^{o}C$ internal temperature cans were discarded because of questionable microbial safety and the $100^{o}C$ cans, because of poor texture (Table 9).

Table 10 compares the 90% yield beef, water bath formed and enzyme inactivated reference samples. The water bath treatment was rated superior to the 90% yield beef and both processes scored greater than the enzyme inactivated reference beef.

The effect of meat roll formation methods and sequence of irradiation and thermal processing on combined treated beef.

Meat rolls were formed by cookhouse processing to a 90% yield or by immersion in a $70^{o}C$ water bath. The rolls were cut into pieces and vacuum sealed in cans and either irradiated at 25 kJ/kg $\pm$ 5% @ $30^{o}C \pm 5^{o}C$ then retorted at $110^{o}C$ to an internal temperature of $90^{o}C$, or retorted then irradiated. The 47 kJ/kg irradiated enzyme inactivated reference sample contained no cooked-out juice. The 90% yield beef cans contained less cook-out juice (6%) than the water bath formed beef cans (Table 11). An excessive juice is detrimental to the appearance of the product, the water bath

procedure for roll formation was discontinued. The sequence of irradiation before or after retorting had little effect on the volume of cooked-out juice.

Beef rolls, water bath formed, scored slightly higher both in preference and organoleptical ratings than the 90% yield beef (Table 12). The beef irradiated after retorting scored slightly higher in preference and sensory characteristics than the beef irradiated before retorting. The 47 kJ/kg irradiated enzyme inactivated reference sample scored lower than the combined treated beef.

<u>The effect of sequence of irradiation and thermal processing on combined treated beef.</u>

Meat rolls were formed by cookhouse processing to a 90% yield. The rolls were cut into pieces and vacuum sealed in cans and irradiated at 25 and 47 kJ/kg. $\pm$ 5% at $-30^{o}C \pm 5^{o}C$ then retorted at $110^{o}C$ to an internal temperature of $90^{o}C$ or retorted then irradiated.

The sequence of irradiation before or after thermal processing and the amount of irradiation dose had no effect on the quantity of cooked-out juice (Table 13).

The irradiation sequence had little or no effect on the preference and sensory scores (Table 14). The 25 kJ/kg irradiated samples scored greater than the 47 kJ/kg. The 25 kJ/kg enzyme inactivated beef scored greater than the combined treated beef. Combined treatment of the 47 kJ/kg irradiated beef did not mask the high dose effect or markedly improve the odor and flavor.

The effect of sequence of irradiation and thermal processing, and irradiation dose on combined-treated beef.

Meat rolls were processed in an electric conduction oven to a 90% yield. The rolls were cut into pieces and vacuum-sealed in cans. The cans were irradiated at 15 and 30 kJ/kg $\pm$ 5% at $-30^{o}C \pm 5^{o}C$, then retorted at $110^{o}C$ to an internal temperature of $90^{o}C$, or retorted, then irradiated. The combined treated canned beef was compared with thermally sterilized canned beef (F_o5.8) irradiated beef, and frozen controls.

The quantity of cooked-out juice in the combined treated beef cans was similar in amount to that contained in the thermally sterilized beef cans (Table 15). The sequence of irradiation and retorting or irradiation dose level had no effect on the quantity of cooked-out juice.

The frozen control beef evaluated for sensory characteristics and preference scored greater than the beef processed by the other methods. (Table 16). The thermally sterilized beef was least preferred. Beef irradiated at 15 kJ/kg and 30 kJ/kg without thermal processing scored superior to 15 kJ/kg and 30 kJ/kg combined treated beef. There was little difference in the ratings of 15 kJ/kg vs. 30 kJ/kg irradiated beef. The sequence of irradiation and retorting had little effect on sensory characteristics or preference of combined treated beef. The combined treated beef scored low in texture and appearance compared to irradiated beef with no thermal processing. All beef samples scored in the acceptable range (5 or above) for sensory and preference scores.

The organic volatile quantity of combined treated beef is greater than the organic volatile quantity of beef processed only by heat or irradiation (Table 17).

The overall results of these experiments indicate that a combined process of low dose irradiation and thermal processing to 90^{o}C produces a slightly more acceptable meat product compared to enzyme-inactivated radappertized beef. The value of the combined treatment, as used, is questionable due to excessive meat juice, and additional processing necessary in combined treatment.

REFERENCES

1. Hannan, R. S. 1955. Scientific and Technological Problems Involved in Using Ionizing Radiations for the Preservation of Food. Special Report No. 61, Department of Scientific and Industrial Research, Her Majesty's Stationery Office, London.

2. Shultz, H. W., Can, R. F., Nordan, H. C., and Morgan, B. H., 1956 Concomitant Use of Radiation With Other Processing Methods of Meat. Food Technol. 10: 233.

3. Stumbo, C. R., 1949. Thermobacteriology as Applied to Food Processing. Advances in Food Research, 2. Academic Press, Inc., New York City, New York.

4. Morgan, B. H. and Reed, J. M., 1954. Resistance of Bacterial Spores to Gamma Radiation. Food Res. 19: 357.

5. Kempe, L. L., 1955. Combined Effects of Heat and Radiation in Food Sterilization. Appl. Microbiol. 3: 346.

6. Kan, B., Goldblith, S. A., and Proctor, B. E., 1957. Complementary Effects of Heat and Ionizing Radiation. Food Res. 22: 509.

7. Sommer, N. F., Fortlage, R. J., Buckley, P. M., and Maxie, E. C., 1967. Radiation Heat Synergism for Inactivation of Market Disease Fungi of Stone Fruits. Phyto-Pathology 57: 428.

8. Purohit, K. S., Manson, J. E., and Zahrandnik, J. W., 1971. Theoretical Evaluation of Combined Irradiation and Thermal Processes in Cylin-lindrical Containers with Gamma Sources. J. Food Sci. 36: 750.

9. Wadsworth, C. K. and Shults, G. W., 1966. Low Temperature Irradiation of Meat. Activities Report 18: 13.

10. Heiligman, F. and Rice, L. J., 1972. Development of Irradiation Sterilized Codfish Cake. J. Food Sci. 37: 469.

11. Shults, G. W., Russell, P. R., and Wierbicki, E., 1972. Effect of Condensed Phosphates on pH, Swelling, and Water-Holding Capacity of Beef. J. Food Sci. 37: 860.

12. Shults, G. W. and Wierbicki. E., 1973. Effect of Sodium Chloride and Condensed Phosphates on Water-Holding Capacity, pH and Swelling of Chicken Muscle. J. Food Sci. 38: 991

13. Shults, G. W. and Wierbicki E., 1974. Effects of Condensed Phosphates on the pH, Water-Holding Capacity and Meat Swelling Properties of Pork Muscle. TR-74-22-FL. U.S. Army Natick Laboratories.

14. AOAC, 1970. "Official Methods of Analysis," 11th Ed. Assn. of Official Agric. Chemists, Washington, D. C.

15. Pearson, D., 1971. "Chemical Analyzing of Food," 6th Ed., p. 377. Chemical Publishing Company, New York, N.Y.

16. Tarladgis, B. C., Watts, B. M., and Younathan, M. T., 1960. A Distillation Method for the Quantitative Determination of Malonaldehyde in Rancid Foods. J. Am. Oil Chem. Soc. 37: 44.

17. Shults, G. W., Howker, J. J., and Wierbicki, E., 1976. Effect of Salt and Foodgrade Phosphate on Texture, Organic Volatiles and Sensory Characteristics of Irradiated and Nonirradiated Pork. J. Food Sci. p.1096 Vol. 41.

18. Peryam, D. R. and Pilgrim, F. J., 1957. Hedonic Scale Method for Measuring Food Preferences. Food Technol. (Supp) 11:9.

19. Steel, R. G., and Torrie, J. H. 1960. Principles and Procedures of Statistics, McGraw-Hill Book Company, 1st Ed.

Table 1

Proximate analysis of been (90% yield) irradiated @ 25 kJ/kg, then retorted to internal temperatures of 70°, 90°, 100°, and 110°C.

Internal Temp	% Water	% Protein	% Fat	FFA	TBA	PV	NaCl Content	Ash
70°C	66.4	22.0	8.0	1.6	0.8	4.8	0.9	2.5
90°C	66.4	21.2	9.1	1.3	0.3	3.8	0.9	2.4
100°C	67.6	22.3	7.3	1.8	0.3	5.8	0.8	2.2
110°C	67.1	23.8	6.4	2.2	0.2	3.7	0.6	2.2
47 kJ/kg Reference Sample	61.2	25.5	9.4	1.3	0.4	10.2	1.1	2.8

Table 2

The percent cooked-out juice of combined treated beef as affected by "yield out of cookhouse" and internal temperature

Internal Temperatures	% of Cooked-Out Juice Beef Roll Yield 100%	90%	80%
70°C*	16.8%	20.6%	13.0%
90°C*	22.7%	21.2%	15.4%
100°C*	18.3%	20.6%	13.1%
110°C*	23.1%	21.5%	13.9%
47 kJ/kg Enzyme-Inactivated Reference Sample	no juice		

*Product irradiated 25 kJ/kg ± 5% @ −30°C ± 5°C prior to thermal processing.

Table 3

The sensory scores of combined-treated beef as affected by

"yield out of cookhouse" and internal temperatures

Beef Roll Yield	Internal Temps.	Sensory Scores * Color	Odor	Texture	Appearance
100%	70°C **	6.7 ± 0.9	7.0 ± 0.5	6.9 ± 1.0	7.3 ± 0.7
	90°C **	5.9 ± 1.5	6.1 ± 1.8	5.5 ± 1.7	6.1 ± 1.8
	100°C **	6.0 ± 1.7	5.8 ± 1.9	5.6 ± 1.5	6.3 ± 1.5
	110°C **	4.4 ± 1.7	4.4 ± 1.2	2.0 ± 0.9	3.1 ± 1.8
90%	70°C **	7.0 ± 0.9	6.4 ± 1.1	6.5 ± 0.5	6.9 ± 0.9
	90°C **	7.0 ± 1.1	6.5 ± 1.0	6.0 ± 1.4	6.6 ± 1.2
	100°C **	6.1 ± 1.5	5.6 ± 1.4	4.9 ± 1.1	5.5 ± 1.0
	110°C **	5.3 ± 1.9	5.5 ± 1.8	2.5 ± 1.0	4.3 ± 1.9
80%	70°C **	5.8 ± 1.3	5.5 ± 1.0	5.6 ± 1.3	5.6 ± 1.4
	90°C **	5.5 ± 1.7	5.9 ± 1.3	5.6 ± 1.7	5.6 ± 1.6
	100°C **	5.1 ± 1.8	5.8 ± 1.1	4.9 ± 1.4	5.3 ± 1.2
	100°C **	4.5 ± 1.7	4.9 ± 2.1	3.1 ± 1.6	4.4 ± 1.6
47 kJ/kg, Enzyme Inactivated Reference Sample		5.1 ± 1.5	4.4 ± 1.3	5.5 ± 1.2	5.3 ± 1.4

* Eight panelists, mean Scores $\pm$ standard deviation

** Product irradiated 25 kJ/kg $\pm$ 5% @ $-30^{\circ}C \pm 5^{\circ}C$ prior to thermal processing

Table 4

Preference scores of combined-treated beef as affected by "yield out of cookhouse" and internal temperatures

Preference Scores*

Internal Temperatures	Beef Roll Yield 100%	90%	80%
70°C**	5.6 ± 1.2	5.7 ± 0.8	6.6 ± 1.1
90°C**	5.3 ± 1.0	6.3 ± 0.7	6.1 ± 0.6
100°C**	5.3 ± 0.8	4.6 ± 1.8	3.6 ± 0.9
47 kJ/kg Enzyme Inactivated Reference Sample	4.4 ± 1.0	4.9 ± 1.2	4.9 ± 1.0

* Eight panelists, mean scores ± standard deviation

** Product irradiated 25 kJ/kg 5% @ -30°C ± 5°C prior to thermal processing

Table 5

The percent cooked-out juice of combined-treated beef as affected by retort temperatures and internal temperatures

% Cooked-Out Juice

Retort Temperatures	Internal Temperatures 70°C	90°C	100°C
110°C*	18.9%	21%	22.6%
120°C*	21.3%	21.3%	22.4%
47 kJ/kg Enzyme Inactivated Reference Sample	No juice		

* Product-irradiated 25 kJ/kg ± 5% @ -30°C ± 5°C prior to thermal Processing

Table 6

Preference scores of combined-treated beef as affected by retort temperatures and internal temperature

	Preference Scores *		
	Internal Temperature		
Retort Temperatures	70°C	90°C	100°C
110°C **	6.2 ± 1.0	6.3 ± 1.0	6.3 ± 1.7
120°C **	5.8 ± 1.2	5.8 ± 1.1	5.6 ± 1.5
47 kJ/kg Enzyme-Inactivated Reference Sample		5.1 ± 0.6	

* Eight panelists, mean score ± standard deviation

** Product irradiated 25 kJ/kg ± 5% @ -30°C ± 5°C prior to thermal processing

Table 7

Percent weight loss of beef rolls as affected by meat rolls formation method

Roll Forming Methods	Forming Loss	Chill Loss	Total
Nonformed, raw meat	0%	0%	0%
90% yield, Cookhouse Process	10.7%	1.8%	12.5%
70°C Water Bath Cook	2.9%	2.4%	5.3%
135°C Oven Cook	6.4%	3.4%	9.8%
Enzyme Inactivated (65°-75°C internal temp.)	22.3%	2.0%	24.3%

Table 8

The percent cooked-out juice of combined-treated beef as affected by meat roll formation methods and internal temperatures

Roll Forming Methods	% Cooked-Out Juice Can Internal Temperature 70^{o}	90^{o}	100^{o}
Nonformed, raw meat	13.5%	13.9%	14.6%
90% Yield, Cookhouse Process*	17.4%	15.6%	16.9%
$70^{o}C$ Water Bath Cook*	19.3%	18.9%	18.9%
$135^{o}C$ Oven Cook*	18.1%	18.7%	18.1%
47 kJ/kg Enzyme-Inactivated Reference Sample	No Cooked-out Juice		

*Product irradiated 25 kJ/kg ± 5% @ $-30^{o}C \pm 5^{o}C$ prior to thermal processing

Table 9

Sensory scores of combined-treated beef as affected by meat roll formation methods and internal temperatures

Quality Characteristics	Sensory Scores * Internal Temperature 70°C	90°C	100°C
	90% Yield - Cookhouse Process **		
Color	6.4 ± 1.5	6.3 ± 1.2	5.7 ± 1.2
Odor	6.4 ± 1.4	6.2 ± 1.5	5.7 ± 1.6
Texture	6.1 ± 1.6	5.4 ± 1.1	3.8 ± 1.6
Appearance	6.5 ± 1.3	5.8 ± 1.6	4.4 ± 1.7
	Water Bath Cook **		
Color	6.3 + 1.1	5.9 ± 1.2	5.8 ± 1.4
Odor	6.3 ± 1.4	6.3 ± 1.1	5.9 ± 1.5
Texture	5.9 ± 1.5	4.8 ± 1.5	3.8 ± 1.9
Appearance	6.2 ± 1.1	5.4 ± 1.0	4.4 ± 2.0
	Oven Cook **		
Color	6.5 ± 1.0	6.0 ± 1.2	5.6 ± 1.3
Odor	6.4 ± 1.3	6.1 ± 1.3	5.7 ± 1.4
Texture	6.1 ± 1.1	4.7 ± 1.6	3.8 ± 1.6
Appearance	6.2 ± 1.0	5.2 ± 1.7	4.3 ± 1.6
	Enzyme Inactivated Reference - 47 kJ/kg.		
Color	6.3 ± 1.1		
Odor	4.8 ± 1.7		
Texture	6.1 ± 1.3		
Appearance	6.2 ± 1.1		

* 15 Panelists, mean scores ± standard deviation

** Product irradiated 25 kJ/kg. +_ 5% @ -30°C ± 5°C prior to thermal processing

Table 10

The physical properties and sensory scores of

combined-treated beef as affected by meat roll formation methods

Process	90% Yield Cookhouse Process **	Waterbath Cook **	47 kJ/kg Enzyme Inactivated Reference Sample
Cooking Time	6-3/4 hrs.	1 hr.	12-1/2 hrs.
Roll Wt. Loss	10% - 12%	2 - 5%	15% - 25%
% Juice in Can	16%	19%	None
		Sensory Scores *	
Color	6.2 $\pm$ 1.2	6.4 $\pm$ 1.3	5.3 $\pm$ 1.5
Odor	6.4 $\pm$ 1.1	6.6 $\pm$ 0.9	5.1 $\pm$ 1.3
Flavor	5.8 $\pm$ 1.1	6.2 $\pm$ 0.9	5.1 $\pm$ 1.5
Texture	5.9 $\pm$ 1.3	5.6 $\pm$ 1.3	4.9 $\pm$ 1.3
Appearance	6.4 $\pm$ 1.1	6.2 $\pm$ 1.2	4.5 $\pm$ 1.4

* 14 Panelists, mean scores $\pm$ standard deviation

** Product irradiated 25 kJ/kg. $\pm$ 5% @ $-30^{o}C \pm 5^{o}C$ prior to thermal processing, $90^{o}C$ internal temperature

Table 11

The percent cooked-out juice of beef as affected by meat roll **formation methods and sequence of irradiation and thermal processing**

	% Cooked-Out Juice	
Roll Formation Method	**Irradiation * Before Thermal Processing**	**Irradiation * After Thermal Processing**
90% Yield Cookhouse Process	14.7%	15.1%
Water Bath Process	20.3%	23.4%
47 kJ/kg. Enzyme Inactivated Reference Sample	no juice	

* Product irradiated 25 kJ/kg. $\pm$ 5% @ $-30^{o}C \pm 5^{o}C$, before or after thermal processing to $90^{o}C$ internal temperature

Table 12

Sensory and preference scores of combined-treated beef as affected by meat roll formation method and sequence of irradiation and thermal processing

Irradiation Sequence	Beef Roll Formation	Color	Odor	Sensory Scores * Flavor	Texture	Appearance	Preference
Irradiation Before	90% Yield	6.0 ± 1.3	6.1 ± 1.0	5.7 ± 1.4	5.1 ± 1.4	5.8 ± 1.3	5.8 ± 1.1
Thermal Processing**	Water Bath	6.0 ± 1.3	6.3 ± 0.9	6.0 ± 1.0	5.4 ± 1.4	5.6 ± 1.3	5.9 ± 1.0
Irradiation After	90% Yield	6.2 ± 1.1	6.4 ± 1.0	6.0 ± 1.2	5.4 ± 1.4	5.9 ± 1.1	5.8 ± 1.0
Thermal Processing**	Water Bath	6.1 ± 1.1	6.3 ± 0.9	6.4 ± 1.1	5.8 ± 1.4	5.8 ± 1.0	6.2 ± 1.0
47 kJ/kg. Enzyme Inactivated Reference Sample		6.1 ± 1.1	5.1 ± 1.3	4.7 ± 1.3	5.8 ± 1.2	6.0 ± 1.0	5.1 ± 1.0

* 10 Panelists, 3 tests, mean scores ± standard deviation

** Product irradiated 25 kJ/kg. ± 5% @ −30°C ± 5°C before or after thermal processing to 90°C internal temperature

Table 13

The percent cooked-out juice of combined-treated beef as affected by the sequence of irradiation and thermal processing

Process	Irrad. Dose	% Juice
Irradiation Before Thermal Processing*	25 kJ/kg.	12.4
	47 kJ/kg.	11.6
Irradiation After Thermal Processing*	25 kJ/kg.	10.6
	47 kJ/kg.	12.1
Enzyme Inactivated Reference Samples	25 kJ/kg.	0.3
	47 kJ/kg.	0.9

* Product irradiated at $-30^{\circ}C \pm 5^{\circ}C$ before <u>or</u> after thermal processing to $90^{\circ}C$ internal temperature.

Table 14

Sensory and preference scores of combined-treated beef as affected by the sequence of irradiation and thermal processing

Irrad Sequence	Irrad Dose	Color	Odor	Flavor	Texture	Appearance	Preferance
		Sensory Scores*					
Irrad before thermal processing**	25 kJ/kg	5.5±1.3	5.9±1.2	5.8±1.3	5.6±1.3	5.9±1.4	5.7±0.8
	47 kJ/kg	4.9±1.7	5.4±1.5	5.2±1.5	5.4±1.4	5.1±1.7	5.1±1.7
Irrad After Thermal Processing**	25 kJ/kg	5.2±1.7	5.5±1.3	5.5±1.3	5.6±1.4	5.5±1.3	5.4±1.1
	47 kJ/kg	5.0±1.5	5.5±1.2	5.2±1.0	5.3±1.5	5.4±1.2	5.4±2.2
Enzyme Inactivated Reference Sample	25 kJ/kg	5.9±1.3	5.7±1.2	5.3±1.5	6.1±1.3	6.2±1.5	5.6±1.4
	47 kJ/kg	5.7±1.4	5.2±1.5	5.4±1.3	5.6±1.6	5.8±1.6	5.3±1.1

* 11 Panelists, 2 tests, mean scores ± standard deviation

** Product irradiated at -30°C ± 5°C before or after thermal processing to 90°C internal temperature.

Table 15

The percent cooked-out juice of beef as affected by thermal sterilization, irradiation, or sequence of irradiation and thermal processing

Process	Wt. Meat	Wt. Juice	% Juice
Thermal Ster. F_o 5.8	333.3 g	36.1 g	9.8%
Irrad. 15 kJ/kg.	611.2 g	11.4 g	1.9%
Irrad. 30 kJ/kg.	621.9 g	2.8 g	0.5%
Irrad. Therm. 15 kJ/kg.*	572.5g	50.2 g	8.1%
Therm. Irrad 15 kJ/kg.*	573.6 g	49.7 g	8.0%
Irrad. Therm. 30 kJ/kg.*	568.7 g	54.0 g	8.7%
Therm. Irrad 30 kJ/kg.*	558.2 g	63.1 g	10.2%

* Products irradiated at $-30^oC \pm 5^oC$ before or after thermal processing to 90^oC internal temperature.

Table 16

Sensory and preference scores of beef as affected by thermal sterilization, irradiation, or sequence of irradiation and thermal processing

Sensory Scores*

Process	Color	Odor	Flavor	Texture	Appearance	Preference
Therm. Ster. F_o 5.8	5.5 ± 1.3	6.0 ± 1.1	5.5 ± 1.2	5.4 ± 1.3	5.3 ± 1.3	5.4 ± 1.2
Irrad. 15 kJ/kg.	6.3 ± 1.4	6.4 ± 1.1	5.8 ± 1.2	6.4 ± 1.1	6.5 ± 1.3	5.9 ± 1.3
Irrad. 30 kJ/kg.	6.6 ± 1.0	6.3 ± 1.2	5.9 ± 1.5	6.5 ± 1.2	6.7 ± 1.1	6.0 ± 1.5
Irrad Therm. 15 kJ/kg.**	6.0 ± 0.9	6.2 ± 0.8	5.8 ± 1.1	5.7 ± 1.3	5.9 ± 1.2	5.8 ± 1.2
Therm. Irrad. 15 kJ/kg.**	6.2 ± 0.9	6.0 ± 1.2	5.8 ± 1.4	5.7 ± 1.5	6.1 ± 1.2	5.8 ± 1.2
Irrad. Therm. 30 kJ/kg.**	6.2 ± 1.1	6.2 ± 1.1	5.9 ± 1.0	5.8 ± 1.1	6.1 ± 1.1	5.9 ± 1.0
Therm. Irrad. 30 kJ/kg.**	5.8 ± 1.2	6.1 ± 1.2	5.9 ± 1.4	6.1 ± 1.5	6.0 ± 1.3	5.8 ± 1.2
Frozen Control	6.5 ± 1.3	7.4 ± 0.7	6.9 ± 1.2	6.5 ± 1.5	6.5 ± 1.5	6.7 ± 1.5

* 11 Panelists, 6 Tests, mean scores $\pm$ standard deviation.

** Products irradiated at $-30^{\circ}C \pm 5^{\circ}C$ before or after thermal processing to $90^{\circ}C$ internal temperature.

Table 17

pH and total organic volatiles of beef as affected by thermal sterilization, irradiation, or sequence of irradiation and thermal processing

Process	pH	Meq. (O_2)/100 g Meat*
Therm. Ster. F_o 5.8	5.7	1.13
Irrad. 15 kJ/kg.	5.9	0.92
Irrad. 30 kj/kg.	6.0	0.94
Irrad. Therm 15 kJ/kg.**	5.8	1.29
Therm. Irrad. 15 kJ/kg.**	5.8	1.31
Irrad. Therm. 30 kJ/kg.**	5.9	1.26
Therm. Irrad. 30 kJ/kg.**	6.0	1.34
Frozen Control	6.1	0.95

* Means of 4-8 replicates

** Products irradiated 15, 30 kJ/kg. ± 5% @ -30°C ± 5°C before <u>or</u> after thermal processing to 90°C internal can temperature.

DEPARTMENT OF THE ARMY
US ARMY NATICK RESEARCH and DEVELOPMENT COMMAND
NATICK, MASSACHUSETTS 01760

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
DEPARTMENT OF THE ARMY
DoD-314